



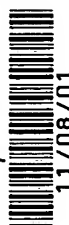
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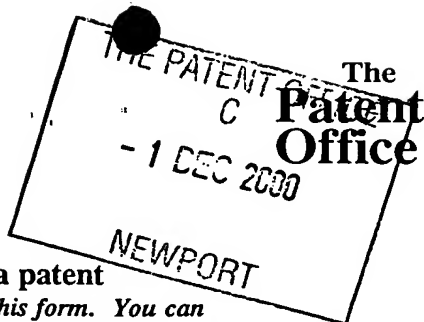
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P01/7700 0.00-0029312.6

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2. Patent application number (The Patent Office will fill in this part)	0029312.6		
3. Full name, address and postcode of the or of each applicant (<u>underline all surnames</u>)	KONINKLIJKE PHILIPS ELECTRONICS N.V. GROENEWOUDSEWEG 1 5621 BA EINDHOVEN THE NETHERLANDS Patents ADP Number (if you know it) If the applicant is a corporate body, give the country/state of its incorporation		
	7419294.001 THE NETHERLANDS		
4. Title of the invention	FLEXIBLE ELECTRONIC DEVICE		
5. Name of your agent (if you have one)	PAUL LEWIS WILLIAMSON		
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a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))			

Patents Form 1/77

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Description	7
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DESCRIPTION

FLEXIBLE ELECTRONIC DEVICE

5 The present invention relates to a flexible electronic device for mounting on a curved or flexible support and a method for fabrication of the same. The ability to fabricate flexible electronic devices is becoming increasingly desirable owing to the trend of incorporating electronics in a growing variety of applications. For example, these devices may be employed in "smartcards",
10 that is, credit card sized pieces of plastic including microcontrollers and secure memory.

 Large area electronics (LAE) made on flexible plastic substrates have been found to suffer from a number of problems. These include low thermal budgets, poor quality devices, cracking and poor adhesion of layers in the
15 semiconductor devices, take up of water, and poor layer to layer alignment due to expansion and contraction of the plastic substrate.

 WO-A-00/46854 describes a technique for producing flexible active matrix displays. Shaped blocks carrying circuit elements are deposited in a slurry onto a flexible substrate which includes complementary recesses. The
20 blocks drop into respective recesses and are then electrically coupled together to form an active matrix.

 In a process disclosed in EP-A-1014452, thin film devices are formed on a separation layer which is provided on a substrate. Hydrogen ions are implanted into the separation layer. The separation layer is then parted from
25 the substrate by irradiating the layer with laser light, this process being accelerated by the effects of the prior implantation step. The devices can then be transferred to another substrate. A large-scale active matrix substrate may be formed by the transfer of a plurality of smaller units that have been fabricated separately on other substrates.

30 The present invention provides a method of fabricating an electronic device comprising the steps of:

(a) forming a predetermined pattern of weakened regions in a layer of rigid material which define contiguous portions of the rigid layer;
(b) providing electronic components on the rigid layer;
5 (c) mounting the rigid layer over a flexible substrate; and
(d) forming flexible connectors which extend between components on different portions. The method preferably includes the step of dividing the rigid layer along the weakened regions.

10 The method combines the advantages of fabricating electronic components on a more robust, brittle material with the versatility of a flexible substrate. It enables a circuit of substantial area to be transferred in toto to a flexible substrate and then to be fractured in a controlled manner so that the combination is flexible. The rigid layer may be fractured in the finished device,
15 or alternatively, the breakage may occur during use of the device.

The method is applicable to the formation of large area electronic (LAE) devices on glass or other rigid materials, or the production of integrated circuits on silicon, for example.

20

The present invention further provides an electronic device comprising a flexible substrate, a layer of rigid material over the substrate having electronic components on its upper surface, contiguous portions of the rigid layer being defined by weakened regions of the rigid layer, and flexible connectors
25 extending between components on different portions.

The invention also provides such a device in which the rigid layer has been divided along one or more of the weakened regions such that the device is flexible. The weakened regions may comprise grooves in one or both faces
30 of the rigid layer.

The rigid layer preferably comprises a brittle material such as glass or silicon, whilst the flexible layer may comprise plastic.

5 The weakened regions may be formed by etching or sandblasting the rigid layer, and may comprise grooves or slots which extend part-way through the layer from one or both faces. Alternatively, they may comprise slots or perforations that pass completely through the rigid layer. They are preferably linear, that is they extend along straight and/or curved lines, and also preferably have a width substantially less than their length, so that breakage
10 occurs in a controlled manner along their length. The weakened regions may be created before or after the electronic components have been fabricated on the rigid layer. The contiguous portions defined by the weakened regions should be sufficiently small that further breakage of the rigid layer beyond the fracture of the weakened regions does not occur during normal use of the
15 device.

The connectors may for example be formed in step (d) by electroplating metal onto the rigid layer. This may include the step of depositing a seed layer prior to electroplating the metal connectors. Areas of photoresist may be
20 defined over the rigid layer prior to electroplating the metal, such that portions of the connectors form bridges over the photoresist, and the photoresist is subsequently removed. The resulting connector is therefore able to flex, thereby maintaining electrical connection of components on different portions despite flexing of the device. Each connector may comprise a single flexible
25 bridge portion that extends over the location where the weakened portion of rigid layer is to fracture, or it may comprise several bridges in a concertina-like structure.

An embodiment of the invention will now be described by way of
30 example and with reference to the accompanying schematic drawings, wherein:

Figures 1A to D show partial cross-sectional side views of steps in the fabrication of a flexible device according to an embodiment of the invention;

Figures 2A to C show partial cross-sectional side views of steps in the fabrication of the connectors 16 illustrated in Figures 1C and 1D;

5 Figure 3 shows a plan view of the flexible device illustrated in Figure 1D; and

Figure 4 shows a smartcard having a flexible electronic device mounted thereon.

10 A process for fabricating a flexible device is illustrated in Figures 1A to D. Figure 1A shows a partial transverse cross-section through the plane of a glass layer 2. Two weakened portions 4 are shown, each consisting of a pair of grooves 6 formed in opposing surfaces 8 and 10 of the layer, which extend perpendicularly to the cross-sectional plane. The grooves may be created by
15 an etching or sandblasting process, for example. The grooves define contiguous portions or islands 14 in the layer therebetween. Electronic components 12 are then formed on the upper surface 8 of the layer (Figure 1B). The components may be provided using known LAE techniques and comprise amorphous, microcrystalline or polycrystalline devices. The process
20 is also applicable to the formation of integrated circuits on silicon, using a layer of silicon in place of the glass layer 2.

Electrically conductive and flexible connectors 16 (Figure 1C) are added to make connections between devices on adjacent islands. The formation of these connectors is discussed below in relation to Figure 2. The glass layer is
25 mounted on a plastic or polymer substrate 18. The assembly is then flexed to fracture the glass layer in a controlled manner, along the weakened portions 4. The arrow 20 illustrates the direction of flexing to fracture the weakened portions 4. It will be appreciated that it may be appropriate to bend the assembly in other directions to fracture other weakened portions which do not
30 run parallel to those shown in Figure 1. The flexing process produces cracks 22 in the weakened portions, as shown in Figure 1D. As a result, the islands 14 can move relative to each other, but remain electrically connected via the

electroplated bridges 16. Typically, the islands are about 5mm by 5mm and the weakened portions around 50 microns wide. This island size is based on the current maximum crystalline silicon chip size of 25mm² used in flexible smartcard technology. This is determined by the extent of flexing that can be withstood before cracking of the integrated circuit chip and/or other types of failure occur. These dimensions may be varied to suit the requirements of particular applications, and the properties of the materials used and the circuitry. It will be appreciated that different materials which may be employed to form the rigid layer 2, which whilst rigid relative to the flexible layer, may have varying degrees of rigidity. The islands should be sufficiently small for further breakage to be avoided during flexing of the device in normal use.

An example of a process for forming the flexible connectors will now be described with reference to Figure 2. Figure 2A shows an enlarged cross-sectional view of a weakened portion or groove 6 in the upper surface 8 of a glass layer 2. Photoresist is deposited onto the surface 8 and then patterned such that three blocks 24, 26 and 28 are formed in the region of the groove 6. Block 26 is located at the base of the groove, whilst blocks 24 and 28 are close to respective edges of the groove. A thin electroplating seed layer 30 (shown in Figure 2B) is then deposited in the direction of arrows 34 using, for example, a shadow mask 32, such that the layer extends over block 26 and to the edges of blocks 24 and 28. The seed layer 30 may consist of copper over chromium, for example.

The connector 16 is then electroplated over the seed layer 30. Nickel or copper may be used to form the connectors. The photoresist blocks 24, 26 and 28 are subsequently removed to leave the finished connector. As discussed above in relation to Figure 1, flexing of the glass layer forms a crack 22 therein below the connector. As can be seen, the presence of the block 26 results in a concertina-like structure in the connector, which extends as a bridge over the crack. The connector is able to accommodate the flexing of the glass layer required for controlled fracture of the glass layer without breaking.

Figure 3 shows a schematic plan view of a flexible electronic device 38 formed using the techniques described above. The device comprises a plurality of contiguous islands 14, each supporting several electronic components 12, and interconnected by connectors 16. Dashed lines 36 indicate the borders of the islands 14.

Electronic devices of the invention may be used in smartcards. A smartcard 40 is illustrated in Figure 4. It comprises a flexible card of plastic 42 having a component 44 mounted thereon which includes an embodiment of a flexible electronic device as described herein. As well as providing memory, these cards may include other features such as biometric testing functions (for example fingerprint sensors) for increased security, keyboards, displays, speakers, microphones, and the like. The invention enables the total chip area to be increased from the presently adopted area of about 25mm². External readers and/or power sources may for example connect to the device via electrical contact surfaces (not shown) included in the component 44.

These devices may also be used to make flexible displays (for example, pLED (light emitting polymer displays) or liquid crystal displays), incorporated into clothing, or mounted on any curved or flexible substrate such as computer mice, car dashboards, lamp shades, toys and the like.

From reading the present disclosure, other variations and modifications will be apparent to persons skilled in the art. Such variations and modifications may involve equivalent and other features which are already known in the design, manufacture and use of electronic devices, and which may be used instead of or in addition to features already described herein.

Although Claims have been formulated in this Application to particular combinations of features, it should be understood that the scope of the disclosure of the present invention also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any Claim and whether or not it mitigates any or all of the same technical problems as does the present invention. Features which are described in the context of separate embodiments may also be provided in

combination in a single embodiment. Conversely, various features which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination. The Applicants hereby give notice that new Claims may be formulated to such features and/or combinations of such features during the prosecution of the present Application or of any further Application derived therefrom.

CLAIMS

1. A method of fabricating an electronic device comprising the steps of:

- 5 (a) forming a predetermined pattern of weakened regions in a layer of rigid material which define contiguous portions of the rigid layer;
(b) providing electronic components on the rigid layer;
(c) mounting the rigid layer over a flexible substrate; and
(d) forming flexible connectors which extend between components on different portions.

10

2. A method of Claim 1 including the step of dividing the rigid layer along the weakened regions.

3. A method of Claim 1 or Claim 2 wherein the connectors are
15 formed in step (d) by electroplating metal onto the rigid layer.

4. A method of Claim 3 wherein step (d) comprises the step of depositing a seed layer prior to electroplating the metal connectors.

20 5. A method of Claim 3 or Claim 4 wherein areas of photoresist are defined over the rigid layer prior to electroplating the metal, such that portions of the connectors form bridges over the photoresist, and the photoresist is subsequently removed.

25 6. An electronic device comprising a flexible substrate, a layer of rigid material over the substrate having electronic components on its upper surface, contiguous portions of the rigid layer being defined by weakened regions of the rigid layer, and flexible connectors extending between components on different portions.

30

7. An electronic device comprising a flexible substrate, a layer of rigid material over the substrate having electronic components on its upper

surface, the rigid layer being divided into contiguous portions along weakened regions of the rigid layer such that the device is flexible, and flexible connectors extending between components on different portions.

5 8. A device of Claim 6 or Claim 7 wherein the weakened regions comprise grooves in one or both faces of the rigid layer.

 9. A device of any of Claims 6 to 8 wherein the rigid layer comprises glass.

10

 10. A device of any of Claims 6 to 8 wherein the rigid layer comprises silicon.

15

 11. A device of any of Claims 6 to 10 wherein the flexible layer comprises plastic.

 12. A device of any of Claims 6 to 11 wherein the connectors comprise electroplated metal.

20

 13. A device of any of Claims 6 to 12 wherein the connectors comprise a bridge-like portion.

25

 14. An article having a device of any of Claims 6 to 13 mounted thereon.

 15. A method of fabricating an electronic device substantially as described herein with reference to the accompanying drawings.

30

 16. An electronic device substantially as described herein with reference to the accompanying drawings.

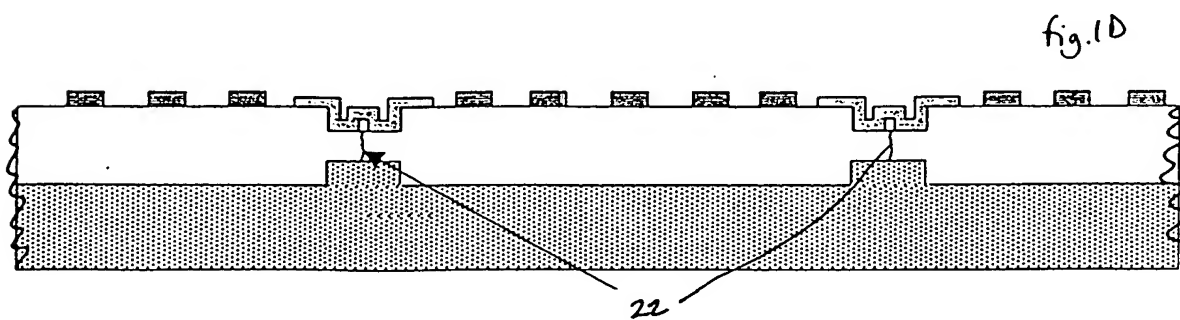
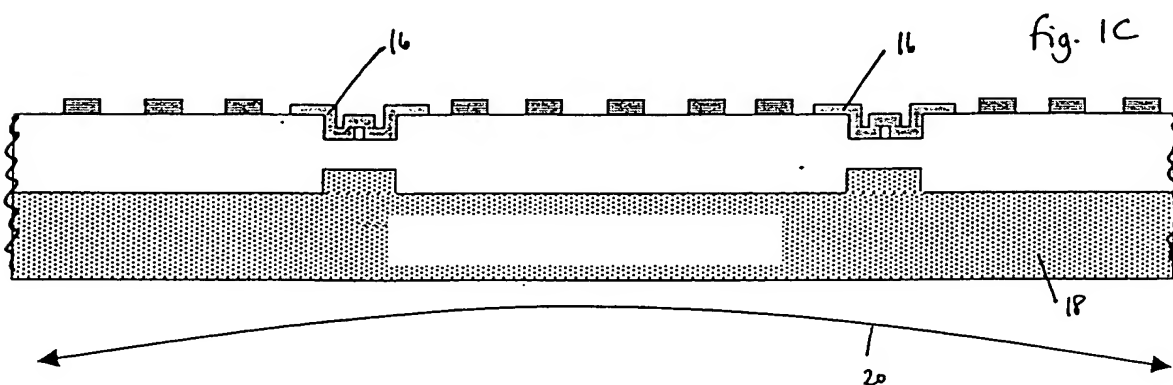
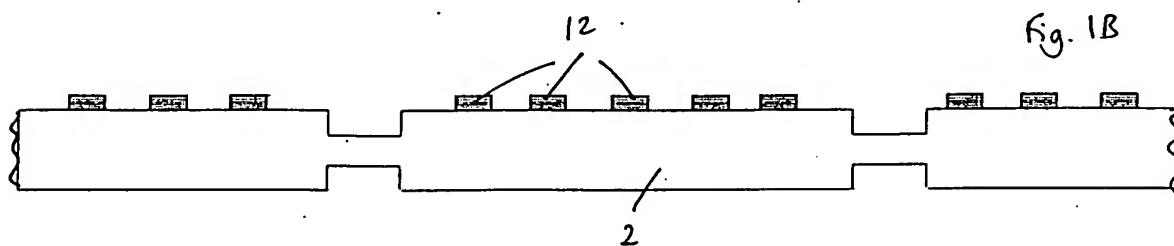
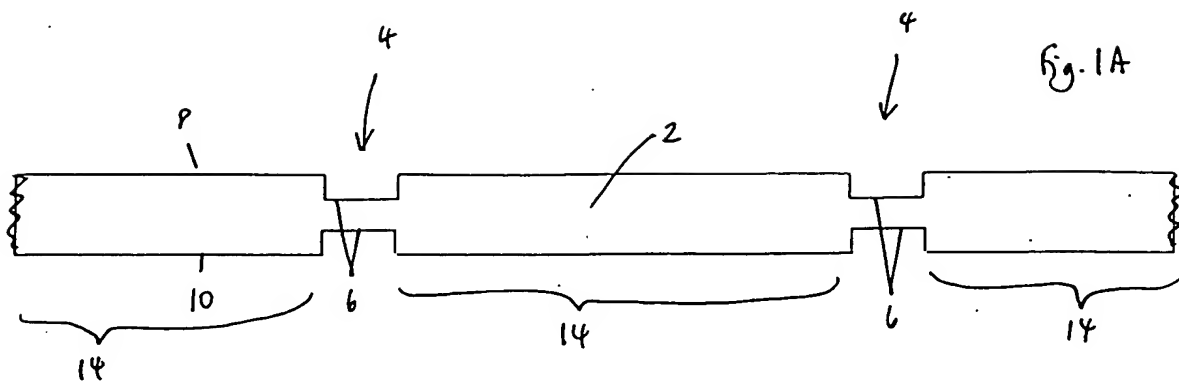
ABSTRACT**FLEXIBLE ELECTRONIC DEVICE**

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An electronic device (38) for mounting on a curved or flexible support (42) and a method for fabrication of the same. The electronic device comprises a flexible substrate (18) and a layer (2) of rigid material over the substrate having electronic components on its upper surface. Weakened regions (6) of the rigid layer (2) define contiguous portions of the rigid layer, and flexible connectors (16) extend between components on different portions. The rigid layer (2) can be fractured along the weakened regions (6) to afford flexibility.

10

Figure 1D



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fig. 2A

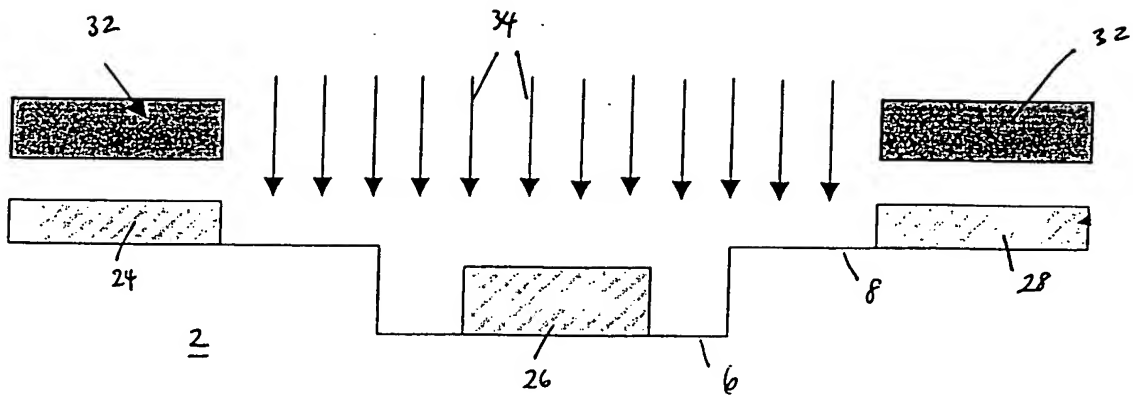


fig. 2B

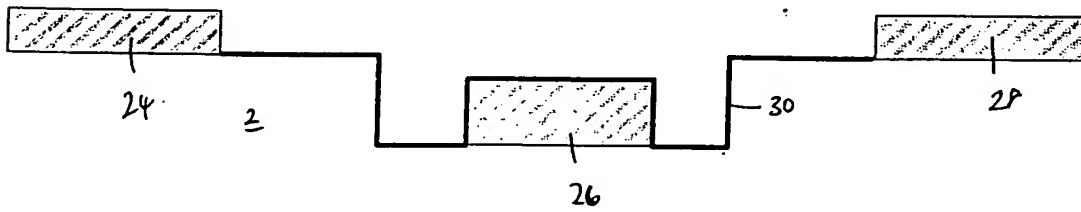
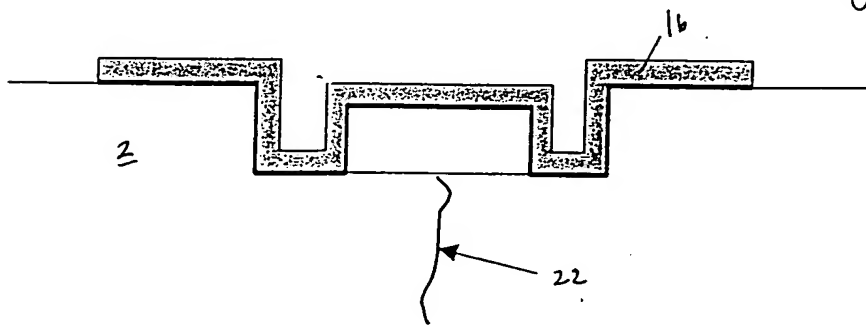


fig. 2C



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Fig. 3

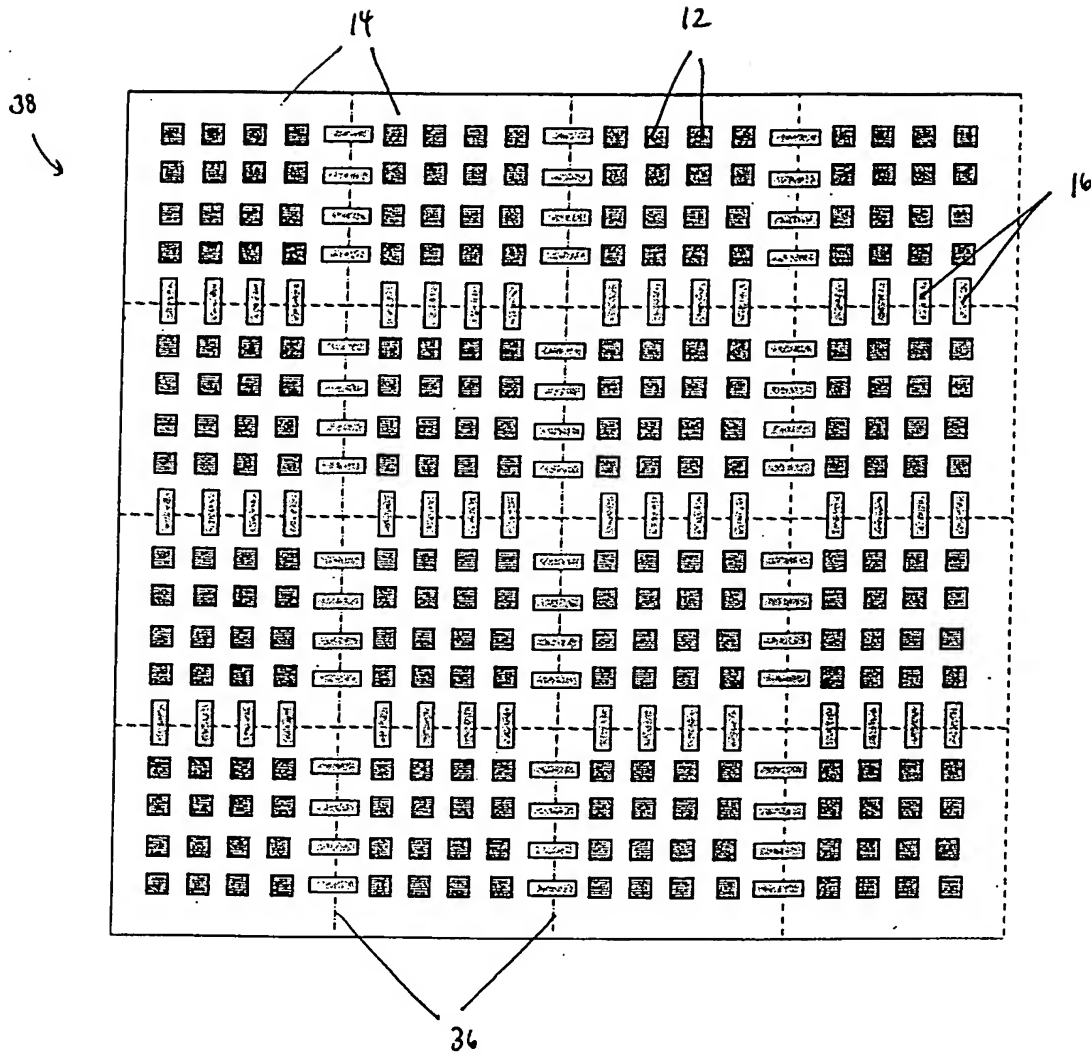
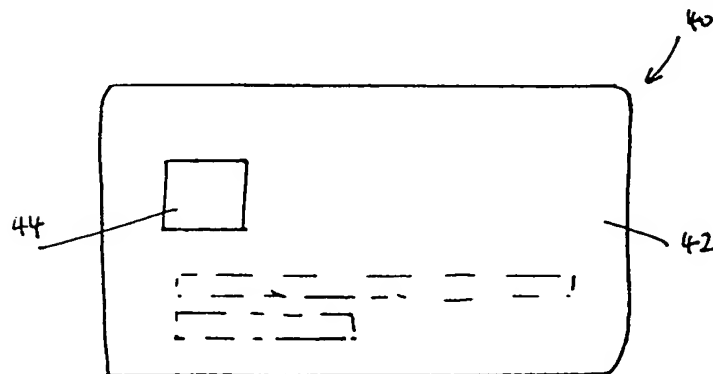


Fig. 4.



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